An Efficient LED Lighting Control System Using WSN for Indoor Environment

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ABSTRACT: Nowadays, energy saving is one of the most important factor to consider. Light and its inefficient use accounts for a great part of world's total energy consumption. Automated lighting systems available to address this concern have not been effective in indoor environments like home and office buildings. This is primarily because indoor environment requirements have to take into account the needs of the users. This paper proposes an LED lighting scheme using Wireless technology, Sensors and tunable parameters which while providing energy saving will also meet the users need.

KEYWORDS: LED lighting control system, minimum light intensity

I. INTRODUCTION

Energy and its efficient use are of concern due to the twin problems of depleting energy resources and its effect on the environment. Energy consumption of consumer electronics is a major contributor. Light accounts for a great part of the total energy consumption. It is estimated that approximately 20% of world's total energy consumption is due to lighting systems.

The invention of light emitting diode (LED) is expected to significantly alleviate the energy consumption of a light, because the LED lighting device consumes 50 percent of the energy consumption compared to the fluorescent lighting device. Related studies of an energy efficient lighting system have been done and are ongoing by various researchers around the world. The technical report from the U.S. Department of Energy shows that about 15 percent of total energy consumption can be reduced via light control based on user's living pattern. Thus the combination of LED and tailored solutions can reduce energy consumption.

User satisfaction is a more crucial factor than cost benefits due to energy saving in a house or office environment. User dissatisfaction can arise out of frequent On-Off, insufficient illumination intensity for his current work. Thus intelligent lighting control systems should be designed considering both energy efficiency and user satisfaction.Many solutions have been implemented and new technologies and methods are continuously being researched to lower the energy consumption of lighting systems. Technology, for example the use of LED against fluorescent lamps and efficient control schemes have been applied to many different applications (Ex: Street lighting, corridor lighting, etc,). However, effective solutions for indoor environments like homes and offices which have user activities and needs different than that of outdoor environments are still to be realized.

Indoor environments present a challenge in terms of the user and his activities. A general On/Off and/or preset dimming control might cause a lot of inconvenience to a user in an indoor environment like a home or office. Therefore, there is a need for a new intelligent lighting control system which should be designed considering both energy efficiency and user satisfaction.

The design goals of the new intelligent lighting control system can be stated as:

- The new intelligent lighting control system should be designed to maximize the utilization of an LED.
- The new intelligent lighting control system should be designed to control based on the situation awareness and hence have communication capability.
- The new intelligent lighting control system should be designed to enhance both energy efficiency and user satisfaction.

This work presents an implementation of a lighting scheme based on the above design goals for LED's utilizing multi sensors and wireless communication technology that can result in potential energy saving in an indoor environment while allowing the user to tune the control to his satisfaction.

II. LITERATURE SURVEY

Pan et al [1] proposes a wireless sensor network-based intelligent light control system for indoor environments. The wireless sensor network is responsible for measuring current illuminations. Lighting devices (whole and local) are managed based on user activities and profiles by two requirement models – binary and continuous satisfaction. An illumination decision algorithm and a device control algorithm were proposed to determine proper illumination and achieve desired optimization goals of the end user.

Park et al [2] proposed lighting control system based on a building automation and control network (BACnet – Building Automation and Control). The system can reduce the energy consumption for lighting loads by 40%. Within this 40% energy saving. 28% of saving can be achieved by ON/OFF control. 12% of saving can be achieved by dimming control.

Uhm et al [3] proposed an LED light system with light sensors, motion sensors, and network interfaces. LED light enabler communicates with context – aware middleware using an intelligent power gateway that determines the optimal power control by analyzing user living patterns using sensing data obtained by devices. In summary, this light control system can control illumination intensity of an LED light based on brightness of surrounding and movement of residents.

Bellido et al [4] proposed building lighting automation system using digital addressable lighting interface (DALI) devices with wireless sensor networks.

Leccese [5] proposed remote-control system can optimize management and efficiency of street lighting systems. Used ZigBee communications which enable more efficient street lamp-system management.

Byun et al [6] proposed an intelligent household LED lighting system considering energy efficiency and user satisfaction. The proposed system utilizes multi sensors and wireless communication technology in order to control an LED light according to the user's state and the surroundings. The proposed system can autonomously adjust the minimum light intensity value to enhance both energy efficiency and user satisfaction. The proposed lighting system reduces total power consumption of the test bed up to 21.9%.

III. THEORETICAL BACKGROUND

It is useful to analyze the operation sequence of an indoor lighting environment as shown below in the figure.
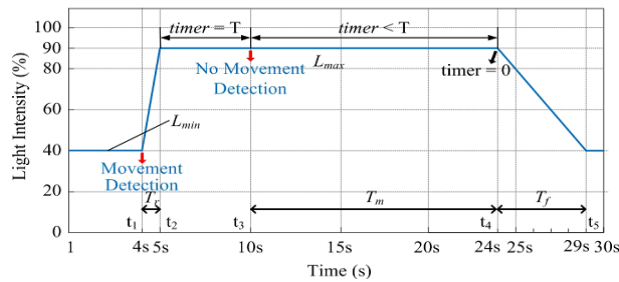

Figure.1- Basic Operating Principles   Source: Net

In the above figure-1,

    Lmin   − minimum light intensity.
    Lmax   − maximum light intensity.
    Tr   − rise time period of light intensity.
    Tm   −time period between no movement detection and that the light intensity begins to falls.
    Tf   − fall time period of the light intensity.

If there is no motion detected, the intensity of the light has to be kept at the Minimum Light Intensity level (Lmin). When motion is detected, the intensity of the light has to increase from minimum light intensity to Maximum Light Intensity (Lmax) with the rise time (Tr) set by the user. When no motion is detected, the intensity of the light has to start reducing after a delay time(Tm) by a rate specified by fall time (Tf) . Both these parameters are specified by the user.

It can be seen that,
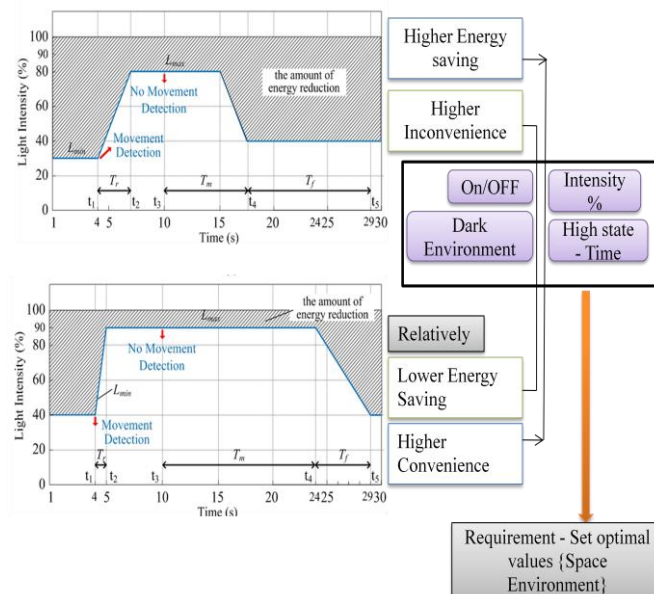If Tr Longer => Tm and Tf are shorter => Greater Energy saving => Higher Inconvenience

Figure.2- Comparison of amount of energy reduction

The above figure.2 illustrates the comparison of amount of energy reduction and user satisfaction. The shaded portion shows the amount of energy reduction. If the rise time is more and fall time is more and the delay time is less after no movement detection, then there is a higher energy saving as illustrated by the first graph. This gives higher inconvenience to the user due to the dark environment.

Relatively second graph illustrates with a very less rise time, gradually slow decrease in fall time and more delay time. This gives lower energy saving but higher convenience to the user. User can set the parameters according to their requirement and the space environment upto to their satisfaction level.

In summary, inconvenience to users will be higher because of frequent light on/off and dark indoor environment, while energy saving is higher. Hence it is necessary to properly set the value according to space environmental characteristics (like frequent or rare user movement, work type, etc,)

IV. PROBLEM DEFINITION

Based on the objective of this work being to design an intelligent LED lighting control system which would result in energy saving as well consider user satisfaction, the following design goals can be stated:
- LED Utilization
- Have communication capability
- Communication means should be barrier free
- Control decisions based on situations
- Enhance energy efficiency and user satisfaction

The above can be realized by the use of Sensors and wireless communication technology and user feedback. The technology will allow the use and control of LED based on the user's state and surroundings.

V. SYSTEM MODEL

Intelligent lighting control system can reduce energy consumption as automatically controlling the intensity of illumination. The main features of the proposed system model are as follows:
- Autonomous control based on user movement
- Autonomous control based on brightness of the surroundings
- Autonomous optimization of system control with the user inconvenience feedback signal.
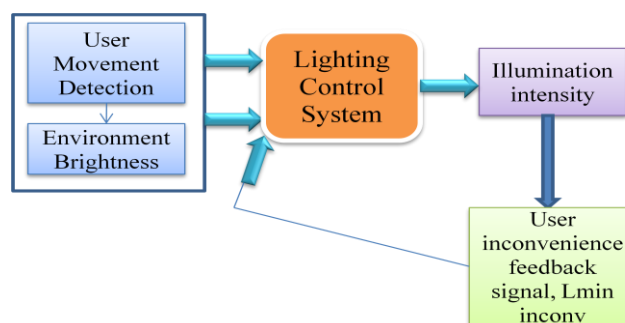
Figure.3- Block diagram of the System Model.

To realize the above, we design the intelligent household LED lighting system with the following control and feedback elements for a single node
- a controller
- a motion detection sensor
- an illumination sensor and
- a wireless communication interface and
- an algorithm to take action based on user feedback

The motion detection sensor of a single node provides a feedback on the user movement and the illumination sensor of the same node provides a feedback on the brightness of the location of the node. Based on the feedback of these sensors and existing parameters, control action and correction is accomplished by the controller for this node. Real time user feedback along with variable parameter settings can be communicated via wireless communication to individual nodes. Multiple nodes can be established each with its set of sensors and controllers. Collective control of the controllers of different nodes along with user feedback provides the desired results.
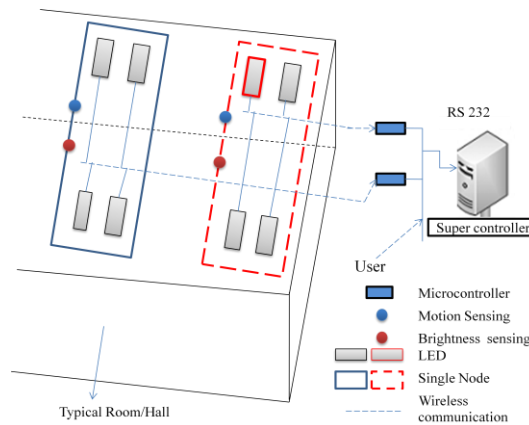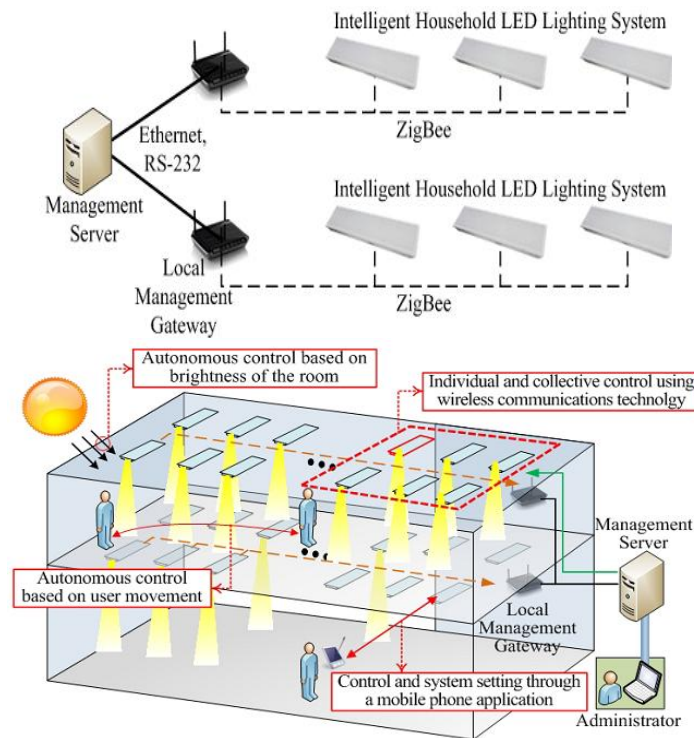

Figure.4- Illustrates the overview for a typical room/hall.

A large room typical of office environments can be visualized as shown in below figures.

Source: Net

Figure.5- Overview of the proposed system with many LED groups

VI. ALGORITHM

The objective of the algorithm is to derive the Lmin value, which can save energy at the maximum without causing inconvenience for users. The input to the algorithm is a signal of inconvenience and a Timer.

The signal of inconvenience is the input/user feedback indicating that the lighting brightness is not sufficient. The Timer provides the interrupt after a given amount of time
.
Below are the algorithmic steps for a minimum light intensity control.

Step 1:
   In the first step, check whether a signal of inconvenience has occurred. If a signal of inconvenience has occurred, then Lminn = (Lmincon+Lminn-1)/ 2, Lminincon = Lminn-1,   n= + 1, and timer= T. And then check again whether a signal of inconvenience has occurred.

Step 2:
       Again, Check whether a signal of inconvenience has occurred. If a signal of inconvenience has occurred, then Lminn = (Lmincon+Lminn-1)/2, Lminincon= Lminn-1, n= n+ 1, and timer= T as in Step 1. If a signal of inconvenience has not occurred, then check whether timeris equal to zero (i.e. the
expiration of a given amount of time, T).

Step 3:
       Again, Check whether timeris equal to zero, if timer is equal to zero, then Lminn = (Lminincon+Lminn-1)/2, Lmincon=Lminn-1, n= n+ 1, and timer= T. And then, check whether Lmincon – Lminincon is less than 5 or not. If timeris not equal to zero, check again whether a signal of inconvenience has occurred.

Step 4-1:
        After check whether Lmincon – Lminincon is less than 5, if Lmincon – Lminincon is less than 5, then terminate this flowchart. If Lmincon – Lminincon is not less than 5, then perform the process of Step 4-2.

Step 4-2:
       Check whether a signal of inconvenience has occurred. If a signal of inconvenience has occurred, then Lminn = (Lmincon+Lminn-1)/2, Lminincon= Lminn-1, n= n+ 1, and timer= T. If a signal of inconvenience has not occurred, then perform again from Step 3.

VII.   PROPOSED IMPLEMENTATION OF HARDWARE

Figure-6 shows the block diagram of the proposed hardware. In this proposed hardware, two nodes are present. Each node has an ARM processor, motion detection sensor, illumination sensor and a group of LED's. Another Arm based board is used as a main controller which is used for setting the parameters and getting the input from the user if there is no satisfaction with light intensity. The two nodes can be set with two different parameter values. Each node displays percentage intensity separately using LCD screens.

If there is any dissatisfaction in the light illumination for the user, then a signal of inconvenience will be sent from the user as a feedback through a mobile application. Parameters set by user will be displayed on the LCD screen and sent to the particular node.
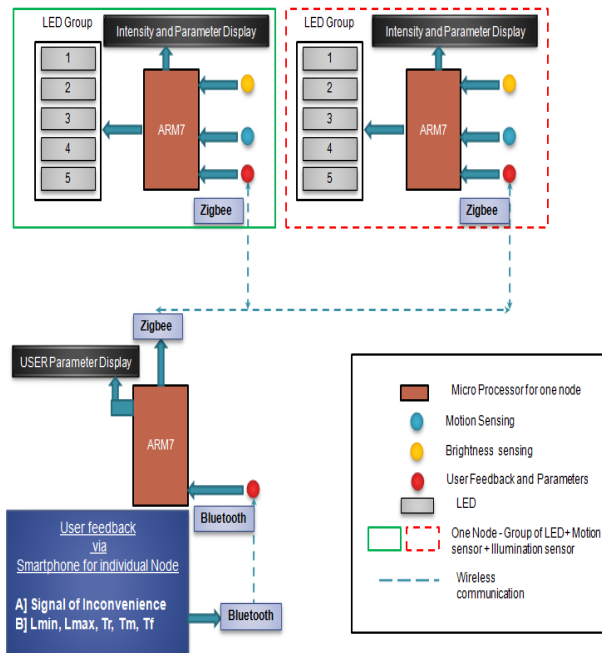
Figure.6- Block Diagram of Hardware implementation

VIII.   SIMULATION RESULTS

Figure 7 shows the simulation result for LCD display. To test the LCD display, it has been connected to LPC2138 microcontroller. The schematic has been designed and simulated by using Proteus software. To simulate the design, coding has been done using Keil4 software. The output string is displayed in two separate lines.
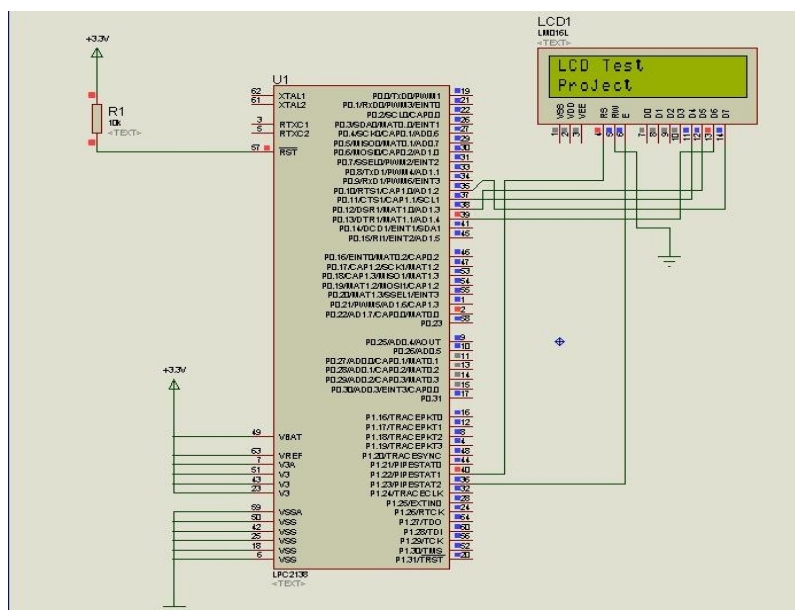

Figure.7-Simulation result for LCD display

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IX. FUTURE SCOPE

User interaction can be made with fine adaptive control tuning and along with intuitive user interface application for different mobile operating systems like Android, IOS and windows mobile.

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